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FIELD OF THE INVENTION

The present invention relates to an installation and to a method intended for thermal insulation, notably of a pipe, by means of vegetable foams. The invention also relates to these vegetable foams having notably characteristics specific to the present application, and their preparation processes.

A suitable field of application of the present invention is the transportation of hydrocarbons produced in wells drilled in the ground. In general, a wellbore is cased over the total length thereof by means of steel pipes or casings. This string is cemented, restoration of communication with the reservoir rock being performed by drilling or perforations. The effluent produced by the reservoir rock is taken up to the surface by means of another tubular string or production tubing placed in the well. This layout thus creates an annular space between the production tubing and the inside of the casing string. It is clear that the pressure and temperature conditions of the effluents evolve as it flows through the production string. It is well-known that pressure and/or temperature variations can be harmful to a proper flow, for example because of paraffin deposits, formation of hydrate crystals or of other mineral or organic deposits resulting from a precipitation. Furthermore, during production of viscous crude, the action of temperature and/or pressure variations can lead to a high viscosity increase which makes pumping and transportation difficult. One solution allowing to overcome these problems consists in thermally insulating the production string so as to control the temperature of the effluent.

BACKGROUND OF THE INVENTION

Several thermal insulation techniques are currently known. The string can be insulated by using tubings comprising an insulating material deposited or fastened outside the tubings. This method is very expensive and the tubings are difficult to handle. The annulus can also be filled with a more or less insulating fluid, gelled gas oil, or rigid foam manufactured in situ. Liquids are not very good insulants, gels are delicate to use in operation and not very temperature stable, manufacture of rigid foams is difficult to control and setting them into the annulus blocks the tubing string in the well, thus preventing complete withdrawal of the string. In fact, it is common to have to pull the whole string of production tubings during production of a well, for example as a result of damage, clogging, or for servicing operations on downhole equipments or installations. In the case of solids present in the annulus, removal or elimination thereof must remain possible.

Document FR-2,536,386 describes a new material intended for thermal insulation of production wells, consisting of an alkaline metal silicate foam which theoretically affords a double advantage : it can be manufactured in situ and it can solubilize in water. In reality, as a result of control difficulties, notably relative to the evolution of the chemical reactions at the bottom of a well, the foam formed is quite heterogeneous and it takes a long time to dissolve.

Document FR-2,741,420 describes a thermal insulation system from an aerogel. This product is expensive and relatively complex to use.

Document EP-087,847 describes a process for preparing a foam from starch gelatinized in the presence of 10 to 30 % water and of an expanding agent such as CO_2

(main characteristic of this foam). This foam however has two major drawbacks, the preliminary processing of the starch (starch gelitinization) and its high water content, which do not allow to use it in wells as a thermal insulant. Furthermore, no application in the field of transportation of hydrocarbons produced in wells drilled in the ground is mentioned.

SUMMARY OF THE INVENTION

The present invention thus relates to a thermal insulation method wherein a volume defined by the space contained between a first enclosure interior to a second enclosure is filled with vegetable foam particles.

The volume thus defined can be an annular space defined by the outside of a pipe placed in another pipe.

The volume of vegetable foam can be solubilized by means of an aqueous fluid so as to allow free pulling of the internal pipe.

The aqueous fluid can be about 1N soda.

The foam particles can have an average size below 5 mm.

The vegetable foam can comprise at least : a flour and/or a non-gelatinized starch, a plasticizer, possibly another additive, a water content below 10 % and preferably below 5 %.

The invention also relates to an installation consisting of a first enclosure placed in a second enclosure. The space contained between the two enclosures comprises a volume of vegetable foam particles used as a thermal insulant.

The enclosures can consist of a string of tubings intended for transportation of a petroleum effluent, placed in another pipe, a well for example.

The vegetable foam particles can have the following properties : thermal conductivity ranging between 0.03 and 0.06 W/m.°K and an at least partial solubility in an aqueous fluid.

The vegetable foam particles can comprise at least : a flour and/or a non-gelatinized starch, a plasticizer, possibly another additive, a water content below 10 % and preferably below 5 %.

The space between the two enclosures can also comprise at least one of the following insulants : silicate foam particles, aerogel foam particles, dry powders.

The invention also relates to a vegetable foam consisting of at least a flour and/or a non-gelatinized starch, one or more plasticizers and possibly one or more additives, and whose water content is below 10 %, preferably of the order of 5 %.

A vegetable foam according to the invention is characterized by the following properties :

- thermal conductivity ranging between 0.03 and 0.06 W/m.°K
- and solubility in an aqueous fluid.

The invention also comprises a process for preparing a vegetable foam, characterized in that it consists in :

- mixing a flour and/or starch with one or more plasticizers, and possibly one or more additives,

- heating the mixture,

- expanding the mixture so as to obtain a foam whose water content is below 10 % and preferably of the order of 5 %.

The preparation parameters relative to baking-extrusion on BC45 can be as follows :

- Material flow rate (kg/h) : 1 to 200,

- % water added : 0 to 10,

- Temperature (°C) : 20 to 300,

- Screw speed (rpm) : 5 to 600.

The plasticizer used can be glycerol whose incorporation proportion can range from 1 to 60 % by weight, preferably from 10 to 40 %.

The additives can be pigments, fungicides, sugars, structuring agents, expanding agents, cellulose fibres, alcohols, whose incorporation proportion can range from 0 to 99 %, preferably from 0 to 30 % by weight.

Mixing, heating and expansion can consist of baking-two-screw or single-screw extrusion at temperatures ranging between 10 and 300°C, preferably between 20 and 250°C.

The « vegetable foam » type particles used within the scope of the present invention are defined as follows :

- type I consisting of at least one cereal flour with at least one plasticizer and possibly one or more allowable additives,

- type II consisting of at least one non-gelatinized cereal starch with at least one plasticizer and possibly one or more allowable additives.

It can be reminded that the term « cereal flour » used in the invention describes vegetable substances coming from cereals whose compositions, according to the various base ingredients, are as follows (percentage by weight) :

- water content below 20 %, preferably ranging between 10 and 15 %,
- carbohydrated compounds content below 85 %, preferably ranging between 50 and 80 %, whose starch content is below 80 %, and preferably ranging between 60 and 75 %,
- proteins content below 30 %, preferably ranging between 5 and 15 %,
- fatty acids content below 10 %, preferably ranging between 0.5 and 5 %,
- minerals content below 5 %, preferably ranging between 0.5 and 2 %,
- fibres content below 20 %, preferably ranging between 5 and 10 %.

The terms carbohydrated compounds, proteins, fatty acids, minerals and fibres designate the multiple products and molecules conventionally described by many reference authors in the field of cereal substance compositions. The following document can be mentioned by way of example : « La composition des aliments. Tableaux des valeurs nutritives », Souci/Fachmann/Kraut - 5th Edition - CRC Press.

The table hereafter gives, by way of example, cereal flours that can be used according to the invention : wheat flour (type T55), corn flour and whole wheat flour.

	Water	Starch	Fibres	Proteins	Fatty acids	Rest
T55 wheat flour	13.7 %	70.6 %	4.1 %	9.84 %	1.13 %	0.63 %
Whole wheat flour	13.2 %	58.16 %	10.3 %	11.73 %	2 %	4.61 %
Corn flour	12 %	66.29 %	9.42 %	8.31 %	2.82 %	1.16 %

As regards starch, which is an important element in a flour, it consists of a mixture of two glucose polymers : amylose and amylopectin. The ratio between these two molecules is different according to the cereals and the varieties, as can be seen in the table hereafter for native wheat and corn and two types of corn varieties.

	Native wheat	Native corn	Waxy type corn	High amylose type corn
% amylose	25	27	0	55-75
% amylopectin	75	73	100	25-45

It can be noted that the amylose/amylopectin ratio can be modified by genetic modifications from natural strains.

For the vegetable foams according to the invention, one or more well-determined cereal varieties can be selected so that, for example, the amylose/amylopectin ratio is the most favourable to obtain the end product according to the use considered.

The cereal wheats or the starch used in the invention can undergo various operations prior to being mixed with the other foam constituents (plasticizers and additives). These operations can be for example :

- drying with a final percentage below 15 %, and preferably ranging between 1 and 3 %, and/or

- crushing with a final grain size ranging between 0.1 and 2000 µm, and/or
- screening, and/or
- turbo-separation.

The percentage by weight of flours and/or starch incorporated to the vegetable foams can range between 1 and 99 %, preferably between 40 and 75 %.

The main purpose of the plasticizers used in the invention is to favour plastification of the starch present in the vegetable matter selected. These plasticizers can be, for example, urea, water or glycerol. The percentage by weight of plasticizers incorporated can range from 1 to 60 %, preferably from 10 to 40 %.

The additives used for obtaining the foams can be of different natures. The following can be mentioned by way of example :

- pigments,
- fungicides,
- sugars,
- structuring agents, melamine for example,
- expanding agents,
- cellulose fibres : cellulose, brans of cereal origin, wood, etc.,
- alcohols.

The percentage by weight of additives incorporated can range from 1 to 60 %, preferably from 1 to 30 %.

The vegetable foams according to the invention have the advantage of being prepared by means of a continuous process. This process allows to mix, to heat and to

expand the ingredients in order to obtain foams that can be advantageously used according to the invention. The temperatures range between 10°C and 300°C, preferably between about 20°C and 250°C. Advantageously, mixing, heating and expanding the vegetable products consist in baking-two-screw or single-screw extrusion. This operation can be carried out in a BC 45 type cooker-extruder marketed by the CLEXTRAL company.

The parameters relative to baking-extrusion with a BC 45 device are given in the following table.

	Material flow rate (kg/h)	Water added (%)	Temperature (°C)	Screw speed (rpm)
Minimum	1	0	20	5
Maximum	200	10	300	600

Advantageously, after expansion, the foams are cooled and cut out by means of any suitable technique in order to obtain particles of a length and/or size suited for optimum use. For applications in annuluses between pipes, the particles preferably have an average size below 5 mm, for example in the shape of a disk, a cylinder, a cube.

Characterization tests have been carried out on a foam prepared according to the specifications mentioned above. It comes in the shape of small cylinders, for example, whose height is substantially equal to the diameter.

A conductivity measurement has first been carried out by means of the Rapid K conductimeter. The table below shows that the 0.038 W/m.°K thermal conductivity measured on the vegetable foam particles is comparable to the conductivity of

polysilicate foam, and much lower than that of a gas oil gel, a solution currently used in wells.

Solubility tests have been carried out from 1 g foam dispersed under stirring in 100 ml liquid. It can be observed that the foam is totally soluble in 1N soda, which attests to its superiority in relation to polysilicate foams which are only partially soluble in 4N soda. These foams therefore have the advantage of allowing free pulling of the tubing.

Thermal stability tests carried out in a drying oven show that the weight loss of these foams is respectively 8 % at 70°C and 27 % at 100°C after being heated for 670 hours (28 days). For these two temperatures and after 28 days, the thermal conductivity of the foams is respectively 0.049 and 0.050 W/m.°K, which remains much below the conductivity values of an industrial insulant such as gas oil. The weight loss can be reduced with foam qualities allowing a low water content, for example below 5 %.

Table : Comparative properties of various insulants

Insulating product	Thermal conductivity in W/m.°K	Removal or elimination
Natural vegetable foam	0.038	Dissolution with 1N soda
Polysilicate foam	0.035	Partial dissolution with 4N soda
Gas oil gel	0.180	Dilution and pumping

BRIEF DESCRIPTION OF THE DRAWING

Other features and advantages of the present invention will be clear from reading the description hereafter of non limitative examples illustrated by the sole figure

diagrammatically showing an oil well equipped with a production string insulated according to the method of the invention.

DETAILED DESCRIPTION

The figure diagrammatically shows, in sectional view, an oil well 1 intended for production of hydrocarbons contained in reservoir rock 2. The wellbore is cased by a string of tubings 3. A series of perforations 4 restores layer/hole communication so that the hydrocarbons can flow as shown by the arrows in the figure. A production string 5, generally consisting of an assembly of about 10-m long tubular elements, is lowered into the well so that the end thereof is close to the perforated zone 4 of casing 3. The upper end of production string 5 is conventionally suspended from the elements of wellhead 6. A series of valves 7 controls the flow rate of the effluent in surface collection pipe 8.

A sealing means or packer 8 insulates the annular space 10 of space 11 filled by the hydrocarbons. Annular space 10 is totally or partially filled by vegetable foam particles as described so as to form an insulating lining at a given depth and over a given height.

Production string 5 preferably comprises a circulation valve 12 which, when it opens, generally by means of a sliding sleeve, allows circulation of a fluid through the inner space of the production tubing to the surface through annulus 10, or in the opposite direction. This circulation valve can be used for driving the insulating foam particles out of the well or for dissolving said particles by soaking them in a suitable fluid.

The invention is not limited to oil wells, it is clear that it can also apply to any equivalent systems, for example double-walled pipelines (pipe-in-pipe) or double-walled reservoir shells.

Furthermore, a mixture consisting of one or more other thermal insulants and of the vegetable foams according to the invention can also be suitable for the thermal insulation method of the invention. Examples of other thermal insulants are aerogel particles, polysilicate foam particles, dry powders, vermiculite for example, fly ashes, carbon black.

A process allowing to obtain a type I foam is described hereafter by way of example.

The cereal flour used in this example is a type T55 wheat flour dried to about 2 % water.

The plasticizer used is glycerol with a 99.9 % purity.

The table hereunder gives the main parameters used during baking-extrusion to obtain the vegetable foams according to the invention.

Temperature (°C)	140
Material flow rate (kg/h)	35
Water added (l/h)	3
Screw speed (rpm)	80

The foams obtained are directly expanded as they leave the cooker-extruder. The particles are about 1 to 2 mm long and 1 to 2 mm in diameter.

These foams eventually contain about 65 % dry cereal matter, 30 % glycerol (% by weight) and 5 % water.